Time Series Spectroscopic & Photometric Observations of Massive DAV BPM37093

Atsuko Nitta[1,2] S.O Kepler[3] André-Nicolas Chené[1] D. Koester[4]
J.L. Provencal[5] S.J. Kleinmani[1] D.J. Sullivan[6] Paul Chote[6]
Ramotholo Safeko[7], Antonio Kanaan[8], Alejandra Romero[3], Mariela Corti[9,10],
Mukremin Kilic[11], M.H. Montgomery[12], D.E. Winget[12]

[1]*Gemini Observatory, Hilo, HI, U.S.A.;* anitta@gemini.edu

[2]*Subaru Telescope, Hilo, HI, U.S.A.*

[3]*Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul,Brazil*

[4]*Universitat Kiel, Kiel, Germany*

[5]*University of Delaware, Newark, DE, U.S.A.*

[6]*Victoria University of Wellington, Wellington, New Zealand*

[7]*South African Astronomical Observatory, Capetown, South Africa*

[8]*Universidade Federal de Santa Catarina, Florinopolis, Brazil*

[9]*Instituto Argentino de Radioastronomía (CCT-La Plata, CONICET),Villa Elisa, Argentina*

[10]*Universidad Nacional de La Plata, La Plata, Argentina*

[11]*University of Oklahoma, Norman, OK, U.S.A.*

[12]*University of Texas at Austin, Austin, TX, U.S.A.*

Abstract. BPM 37093 was the first of only a handful of massive (1.05+/-0.05 Msun; Bergeron 2004;Koester & Allard 2000) white dwarf pulsators discovered (Kanaan et al. 1992). These stars are particularly interesting because the crystallized mass-fraction as a function of mass and temperature is poorly constrained by observation, yet this process adds $1-2$Gyr uncertainty in ages of the oldest white dwarf stars observed and hence, in the ages of associations that contain them (Abrikosov 1960; Kirzhnits 1960; Salpeter 1961). Last year, we discovered that ESO uses BPM 37093 as a standard star and extracted corresponding spectra from the public archive. The data suggested a large variation in the observed hydrogen line profiles that could potentially be due to pulsations, but the measurement did not reach a detection-quality threshold. To further explore this possibility, though, we obtained 4hrs of continuous time series spectroscopy of BPM37093 with Gemini in the Northern Spring of 2014. We present our preliminary results from these data along with those from the accompanying time series photometric observations we gathered from Mt. John (New Zealand), South African Astronomical Observatory (SAAO), Panchromatic Robotic optical Monitoring and Polarimetry Tele-

scopes (PROMPT) in Chile, and Complejo Astronomico El Leoncito (Argentina) to support the Gemini observations.

1. Gemini Spectrum

We obtained approximately 4hrs of continuous time series spectra using GMOS-S at Gemini South. The integration time for individual exposure was 20sec, resulting in cycle time of about 35sec and total 380 frames of time series spectra. The data were taken in 1âĂİ or better, photometric and dark sky condition. The combined spectra which has equivalent to 7600sec integration time, has very high signal-to-noise which we used to fit with Koester models (Koester 2010). We have three equally good fits with different parameters, depending on slightly different treatment of the data and/or wavelength range used.

- $T_{eff} = 11,451$K, log $g = 8.792$ using the combined spectrum up to 4950Åwhere there is a gap in the data corresponding to a gap between CCDs.
- $T_{eff} = 11,268$K, log $g = 8.823$ using the combined spectrum up to 4950Åas above and cleaned up the high/low points due to the bad pixels which were not cleaned up during the reduction.
- $T_{eff} = 11,370$K, log $g = 8.843$ using the combined spectrum up to 5200Å, cleaned up the high/low points due to the bad pixels which were not cleaned up during the reduction, and. adjusting the slope of the red part of the Gemini spectrum to make up for incomplete flux calibration.

The three results are consistent with previous determinations (Bergeron et al. 2004; Koester & Allard 2000). Looking at the fits (which we do not show here), it is not easy to decide which is the best fit. But the 3rd fit which takes care of the shortcoming of the data reduction carried out likely is the best among the above.

The left figure in Figure 1 shows individual time series spectra in black along with the medium spectrum in white. The spectra variation, mainly in flux, is seen, as one expects in a pulsator like BPM37903. The left figure in Figure 1 is the stacked spectra over time or the “running spectra”. The 1st spectra in time is at the bottom of the y-axis and the 380th, the last spectrum at the top of the y-axis. We don’t see any large line profile variation as we originally thought we saw in the archived VLT spectra. We further found out that the calibration of the VLT spectra are not very accurate and the uncertainties are as large as the variation we were seeing.

2. Time Series Analysis

We show part of the photometric data gathered by the Whole Earth Telescope (WET) around the time of the Gemini observation (which took place during the 3rd panel from the top). We have three lightcurves from Gemini data. We constructed a lightcurve by integrating the Gemini spectra in wavelength. We also derived T_{eff} and log g from each spectrum and we plotted them over time as shown in 2nd and 3rd panel of Figure 2. We call them "lightcurves" of T_{eff} and log g. The Fourier transform of the three Gemini

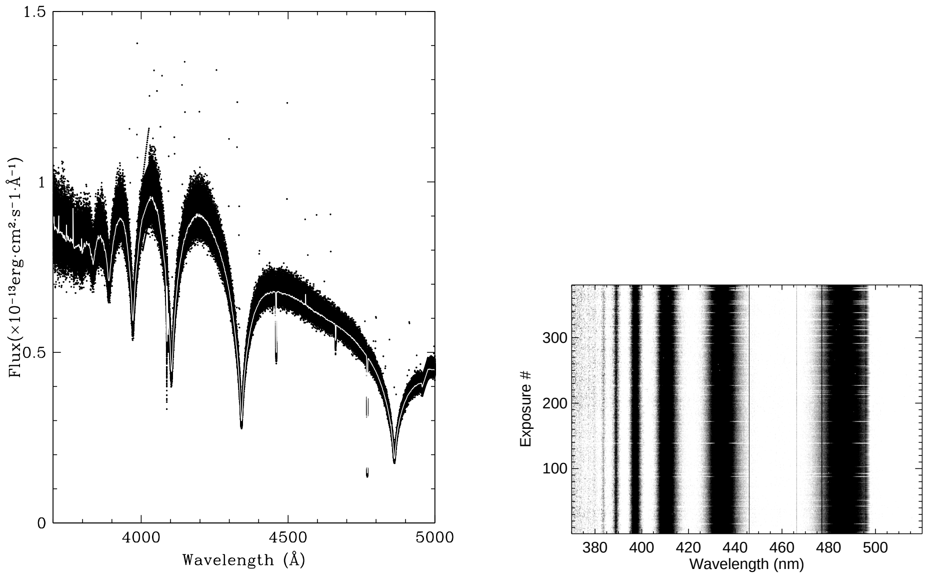

Figure 1. The left figure shows all the individual Gemini spectra in black. The white one is the combined spectrum. The right figure shows the "running spectrum".The first spectrum observed is at the bottom and the last, 380th one, is at the top (i.e. time increase along the y-axis)

lightcurves and WET ligthcurve are shown in Figure 3. The WET data clearly shows two dominant modes, 549sec which has been observed in the past and 625sec mode which has not been observed before. We have checked via running Fourier transform of the WET data that this mode was stable throughout the WET run which are fortunate since BPM37093 has shown amplitude modulations during WET runs in the past. The surprise is the complete lack of any significant peaks in the Gemini data. We are at this time not certain of why this is. We are investing the cause of this – timing inaccuracy of Gemini data, data reduction introducing some artifacts etc. So far we have not identified any mistakes we might have made. Once we resolve any issues we might find, our plan is to look into chromatic amplitude using the spectroscopic data for this massive puslator to determine the ℓ identification of the modes observed.

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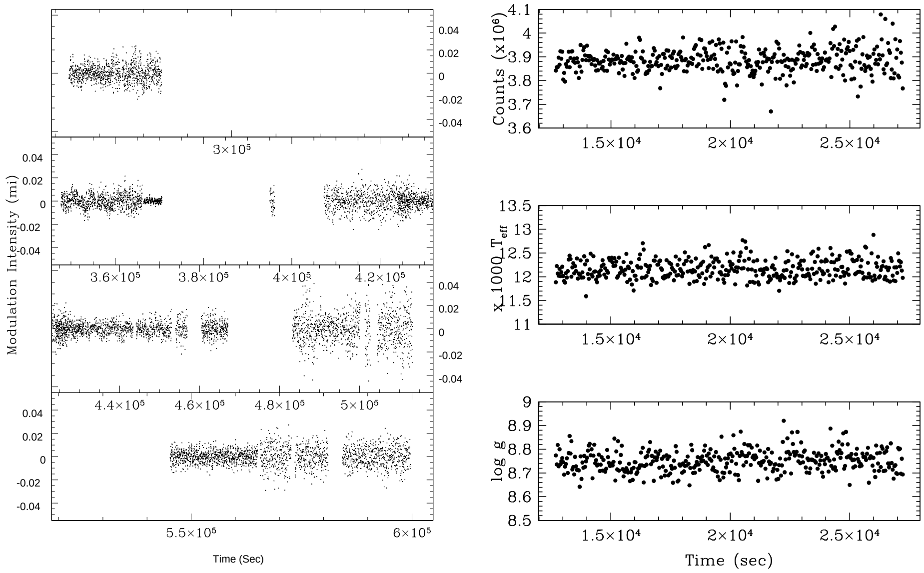

Figure 2. Left:Lightcurve gathered by WET around the time of Gemini observations. RIGHT: Lightcurves created by Gemini data. Top panel shows the lightcurve created by integrating the individual spectrum, the middle panel shows the lightcurve created by T_{eff} estimates of individual Gemini spectrum. The bottom panel shows the lightcurve created by log g estimates of individual spectrum. Bottom Right figure: Fourier transform of lightcurves shown on the bottom left figure and the WET data.

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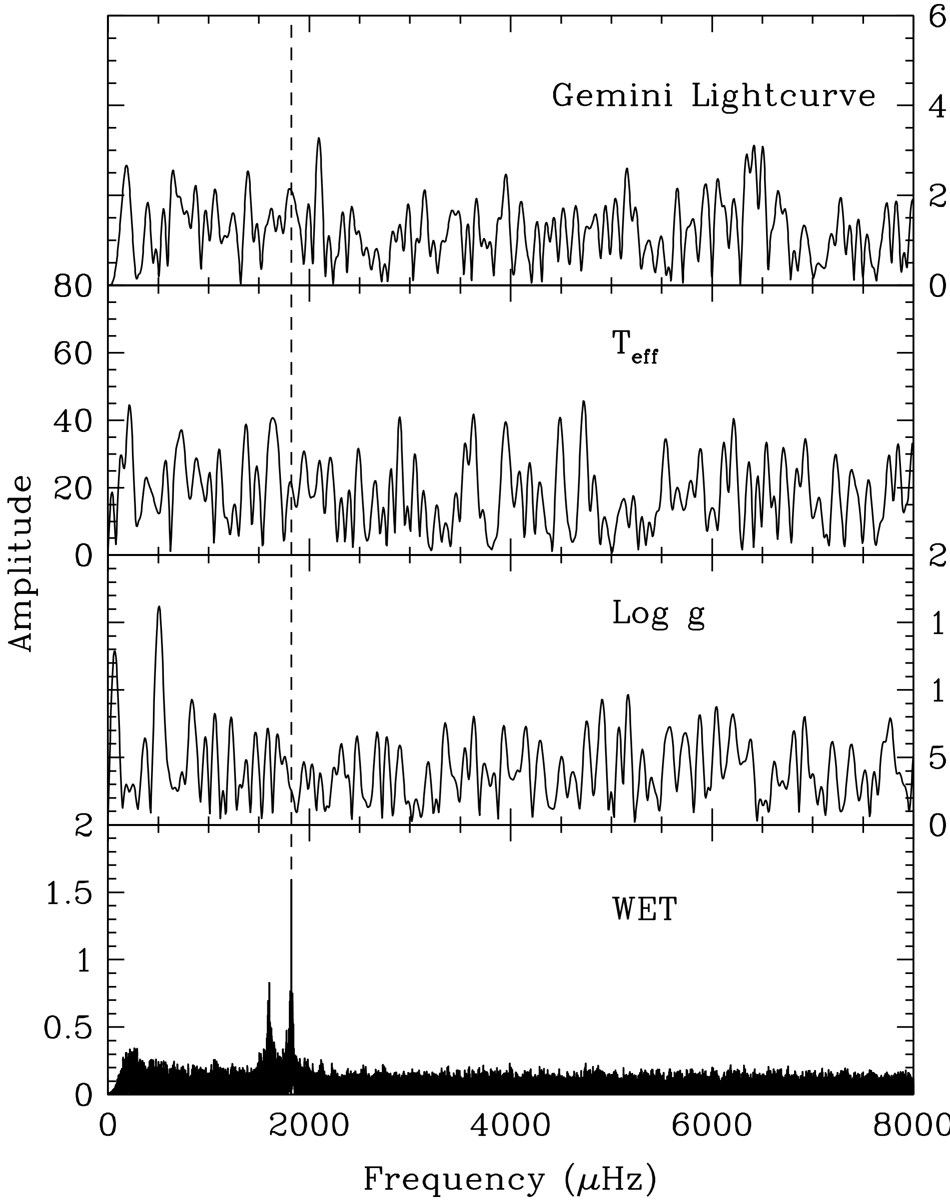

Figure 3. Fourier transform of the various lightcurves shown in Figure 2.